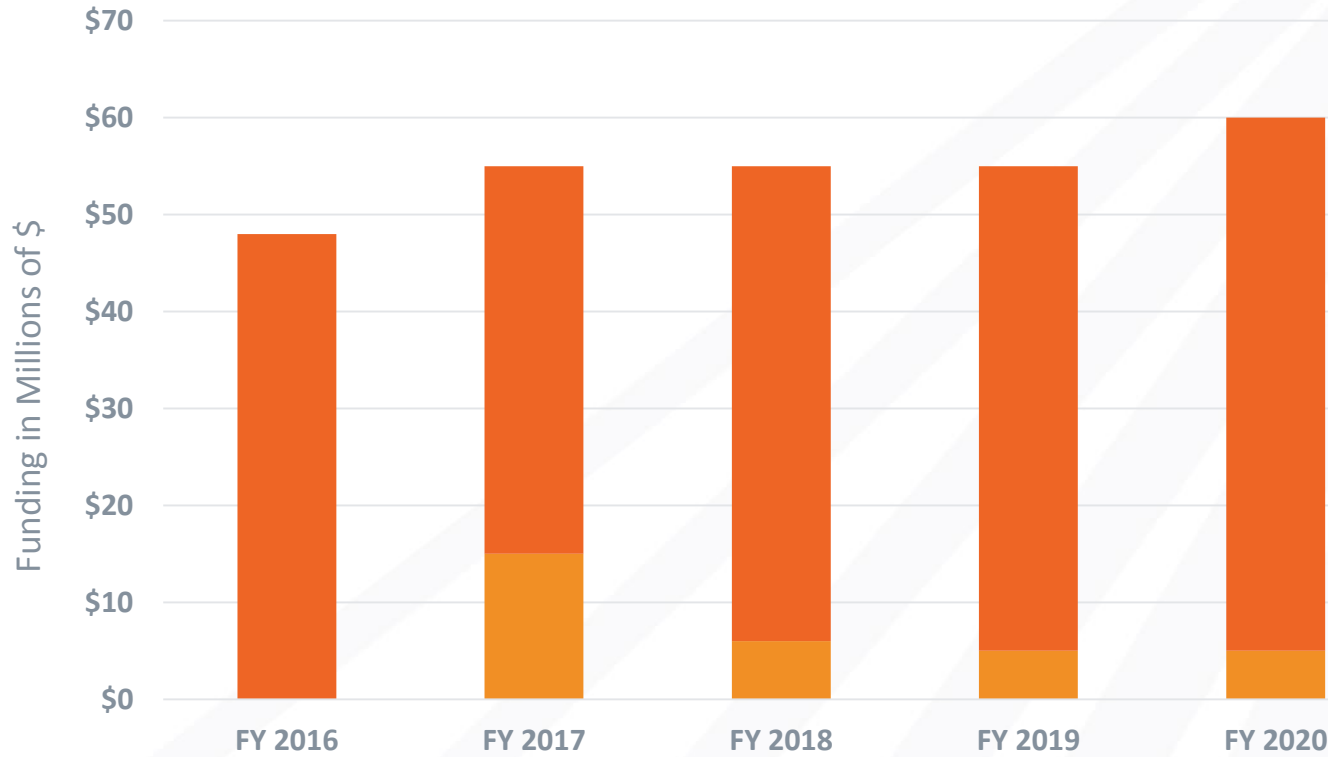


# Concentrating Solar-Thermal Power Introduction

Avi Shultz  
Program Manager

# CSP Program Congressional Budget Overview

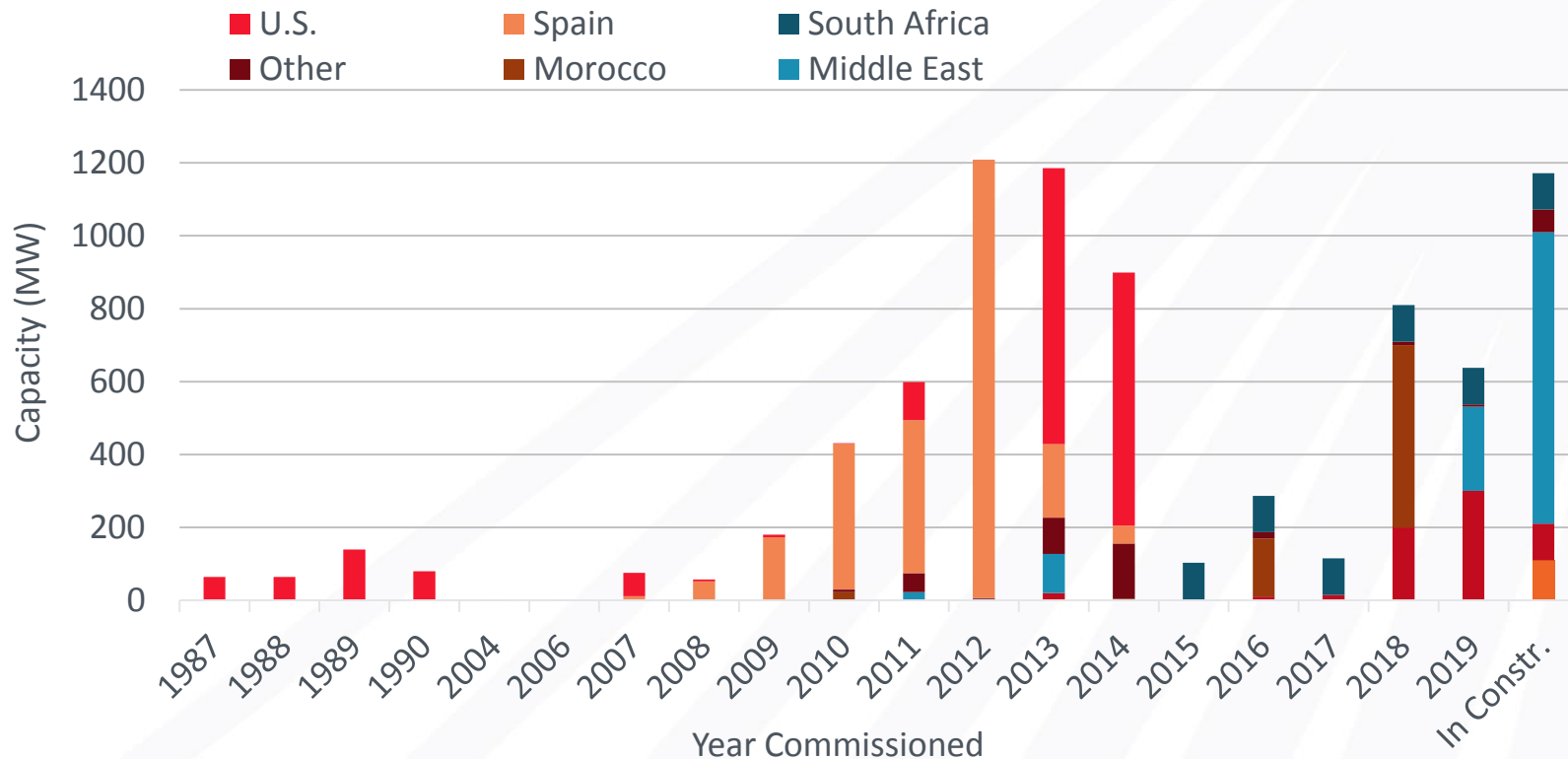


Congress has consistently appropriated funds for “concentrating solar power research, development and demonstration”

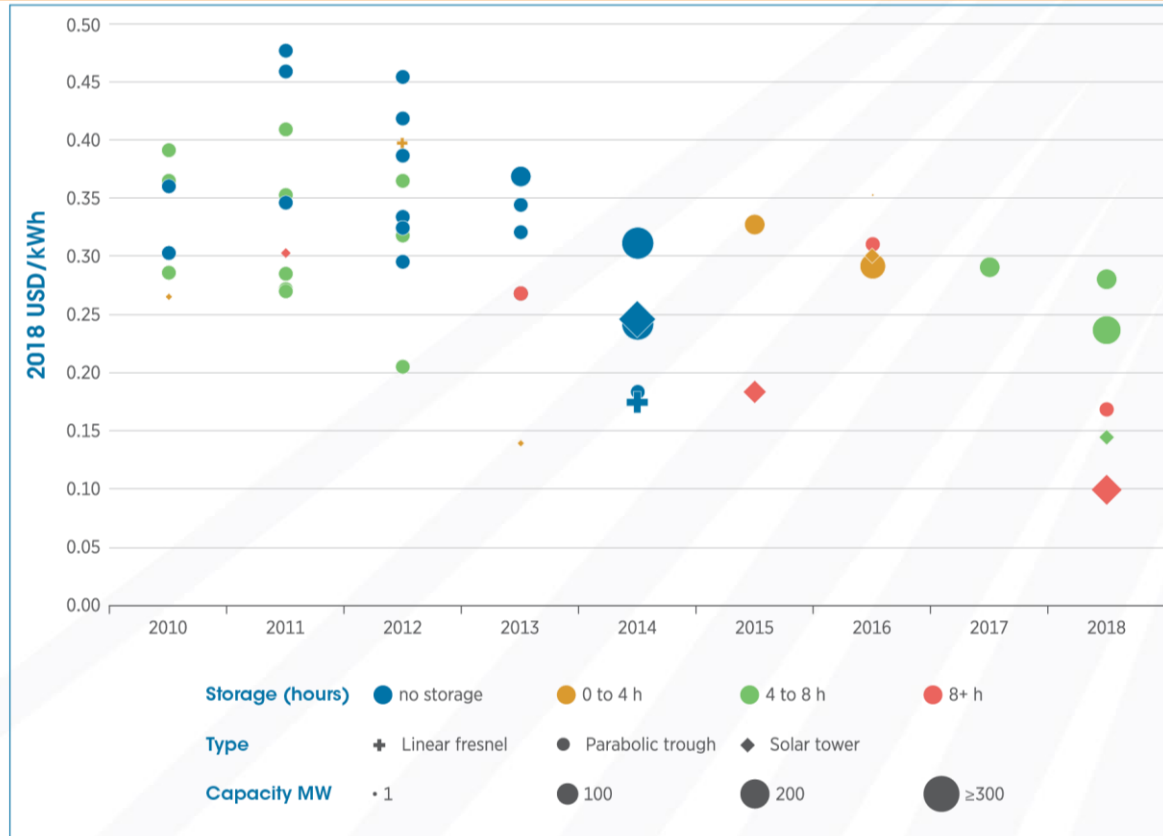
Starting in 2017, received congressional direction to fund research on thermal desalination

\*Does not reflect CSP-relevant funding from other SETO subprogram

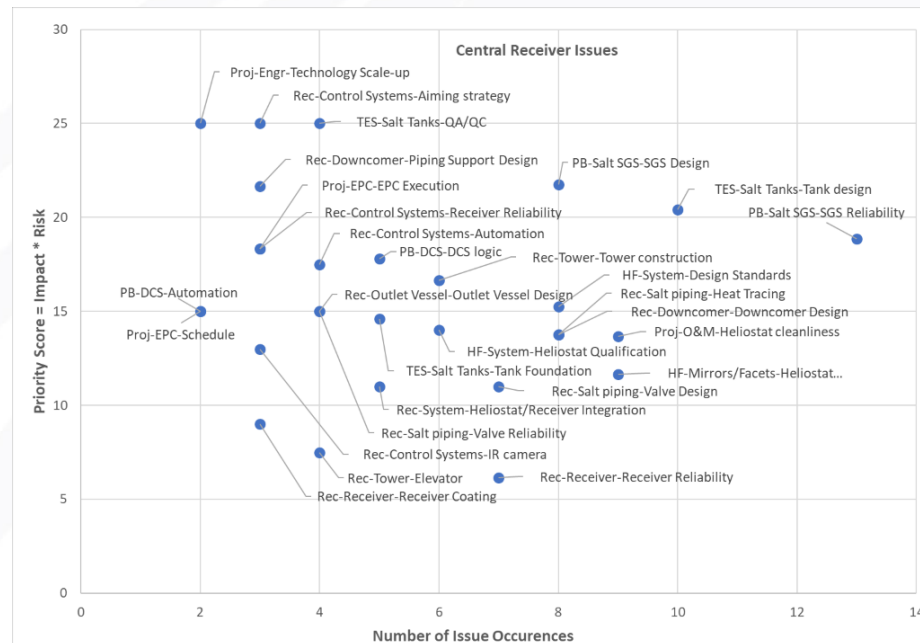
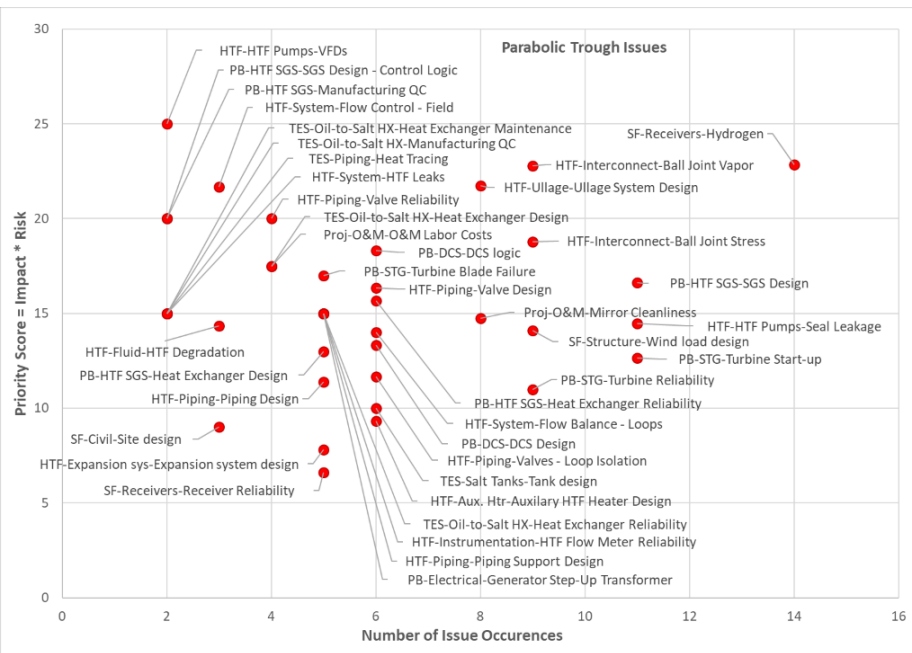
## 6.9 GW CSP Deployed Worldwide



# Global CSP LCOE



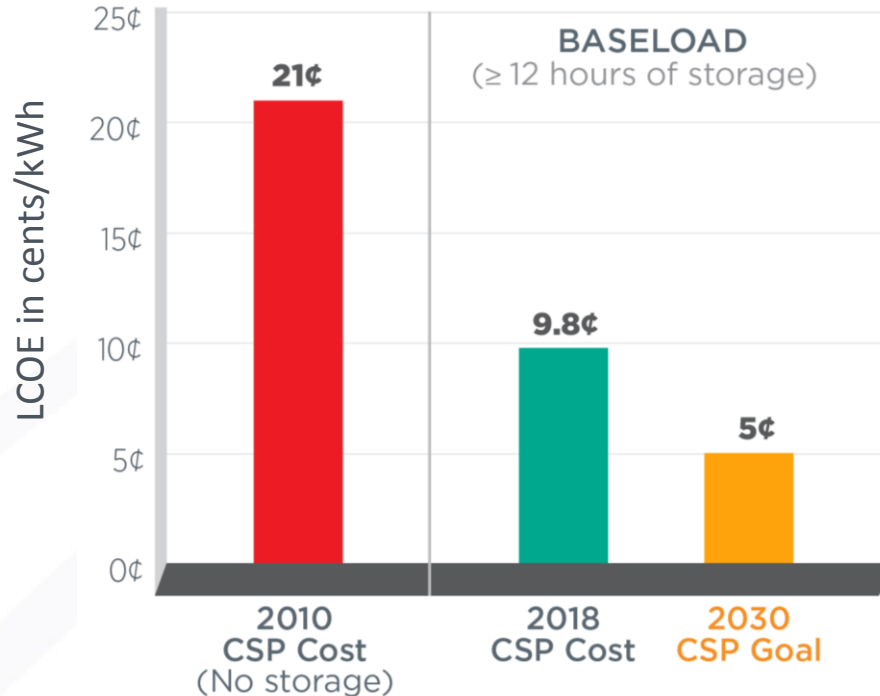
# Documenting CSP Best Practices



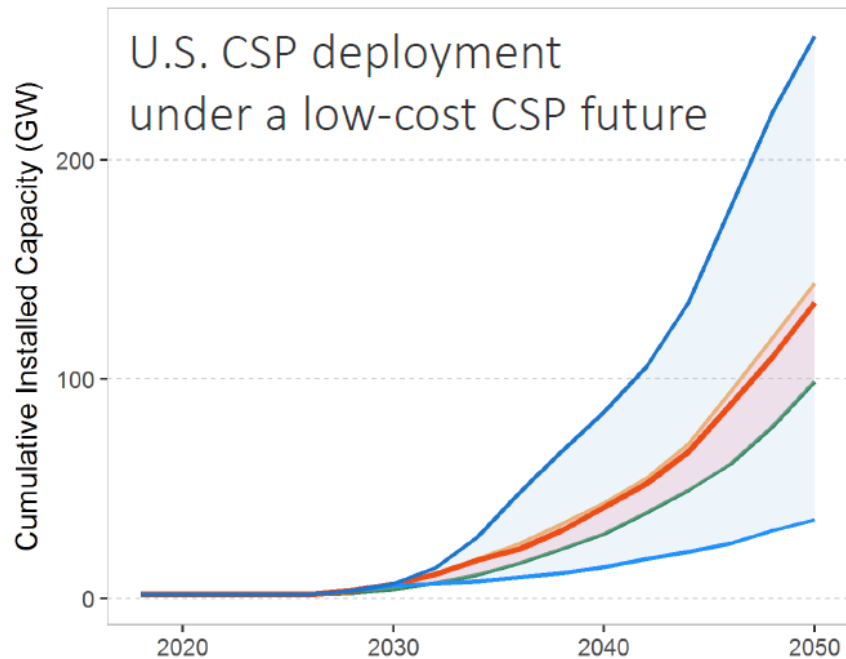
NREL; PI: Mark Mehos  
Report in preparation

# Progress and Goals: 2030 CSP Goal

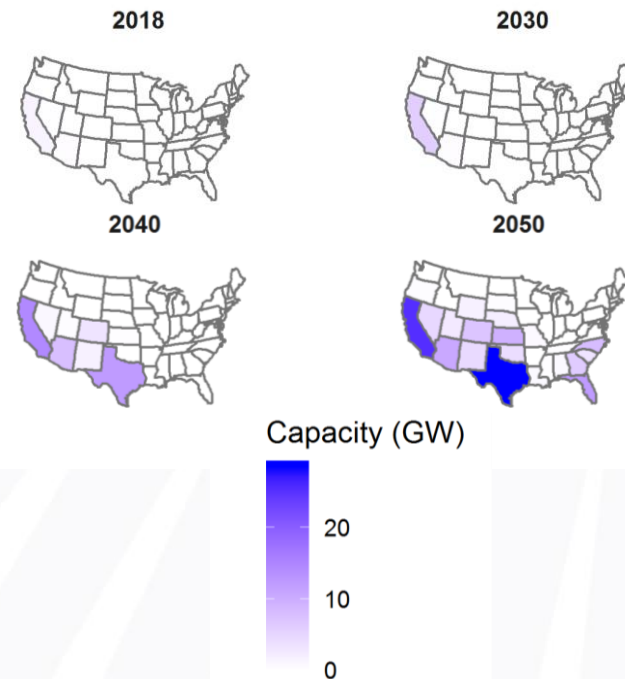
The office's 2030 cost targets for CSP baseload ( $\geq 12$  hours of storage) plants will help make CSP competitive with other dispatchable generators.



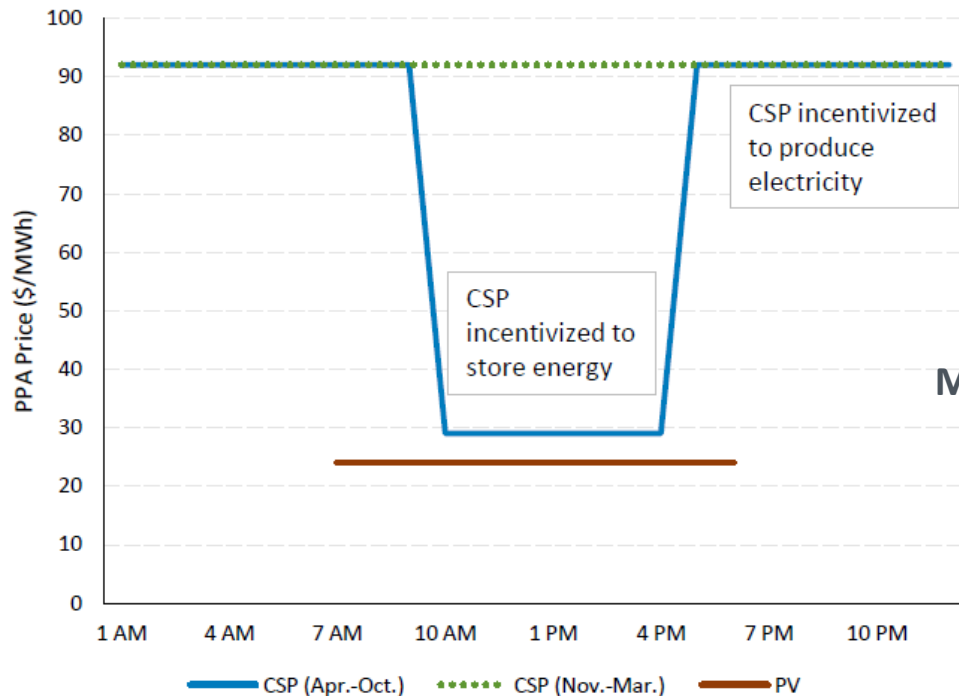
# Potential CSP Deployment in the US if DOE CSP and PV 2030 Cost Targets are Achieved



- High NG Price
- High RE Cost
- Low NG Price
- Low RE Cost
- LowCost-CSP-PV



# Commercial Developers are Optimizing CSP/PV Hybridization



## DEWA IV – Dubai

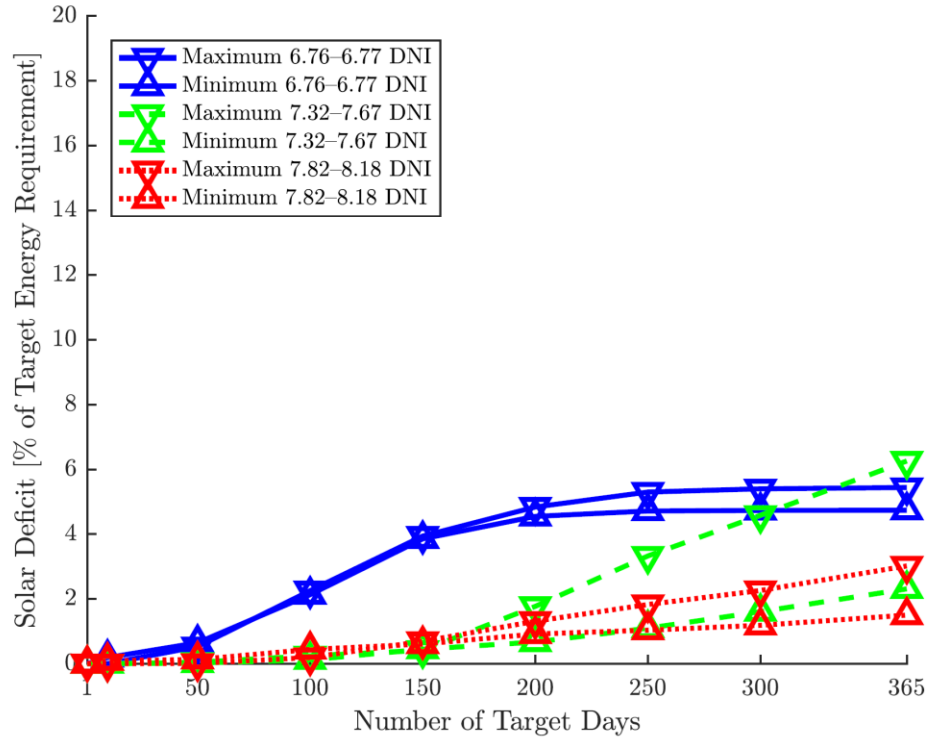
- Developer: ACWA Power
- PPA signed at \$73/MWh
- 950 MW total capacity
  - 200 MW x3 Troughs with 10 hours TES
  - 100 MW Tower with 15 hours TES
  - 250 MW PV

## Midelt 1 – Morocco

- Developer: EDF/MASDAR/Green of Africa
- PPA signed at \$71/MWh
- 400 MW PV
- 400 MW Trough with 5 hours TES
- Excess PV electricity will be stored in molten salt TES

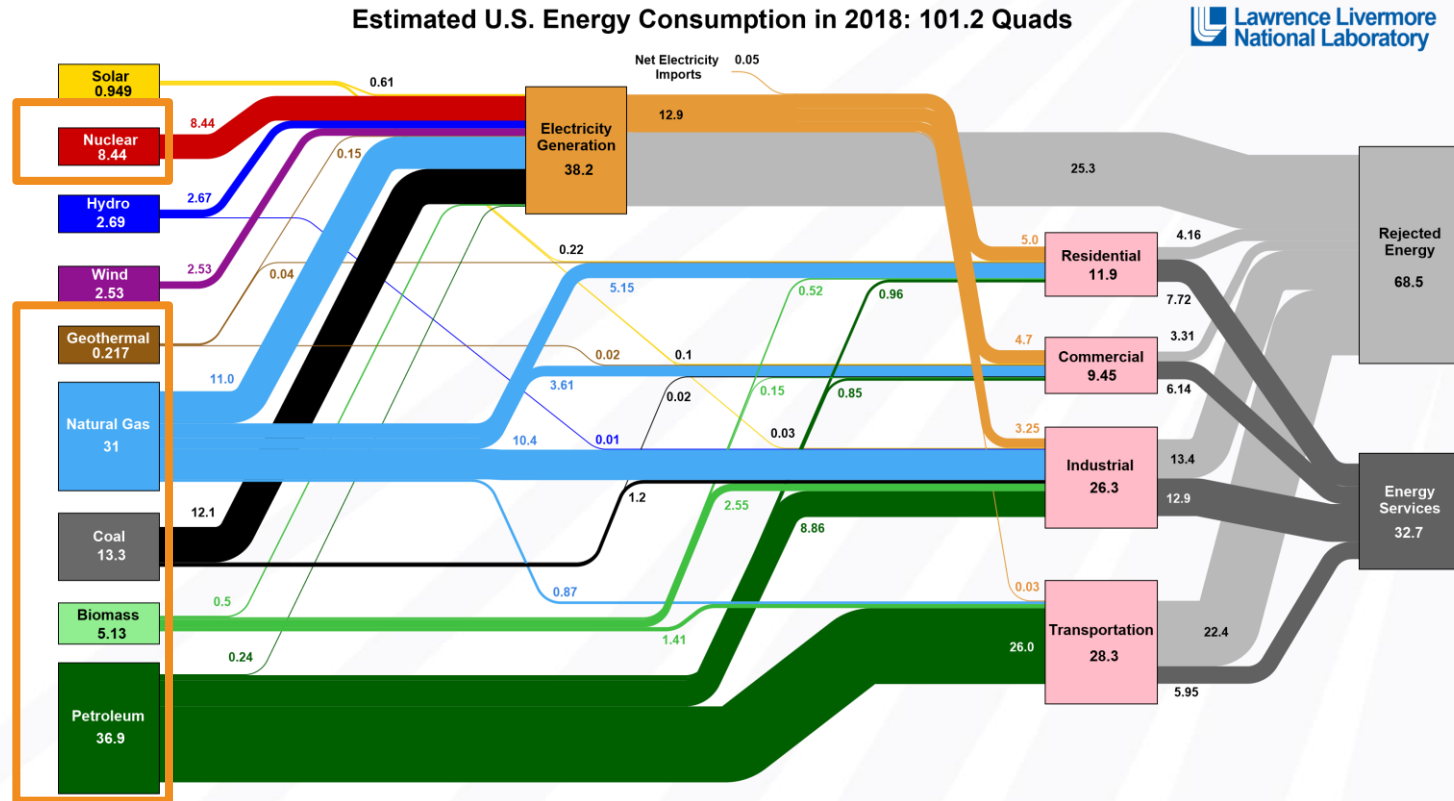


# Value of CSP to the Grid

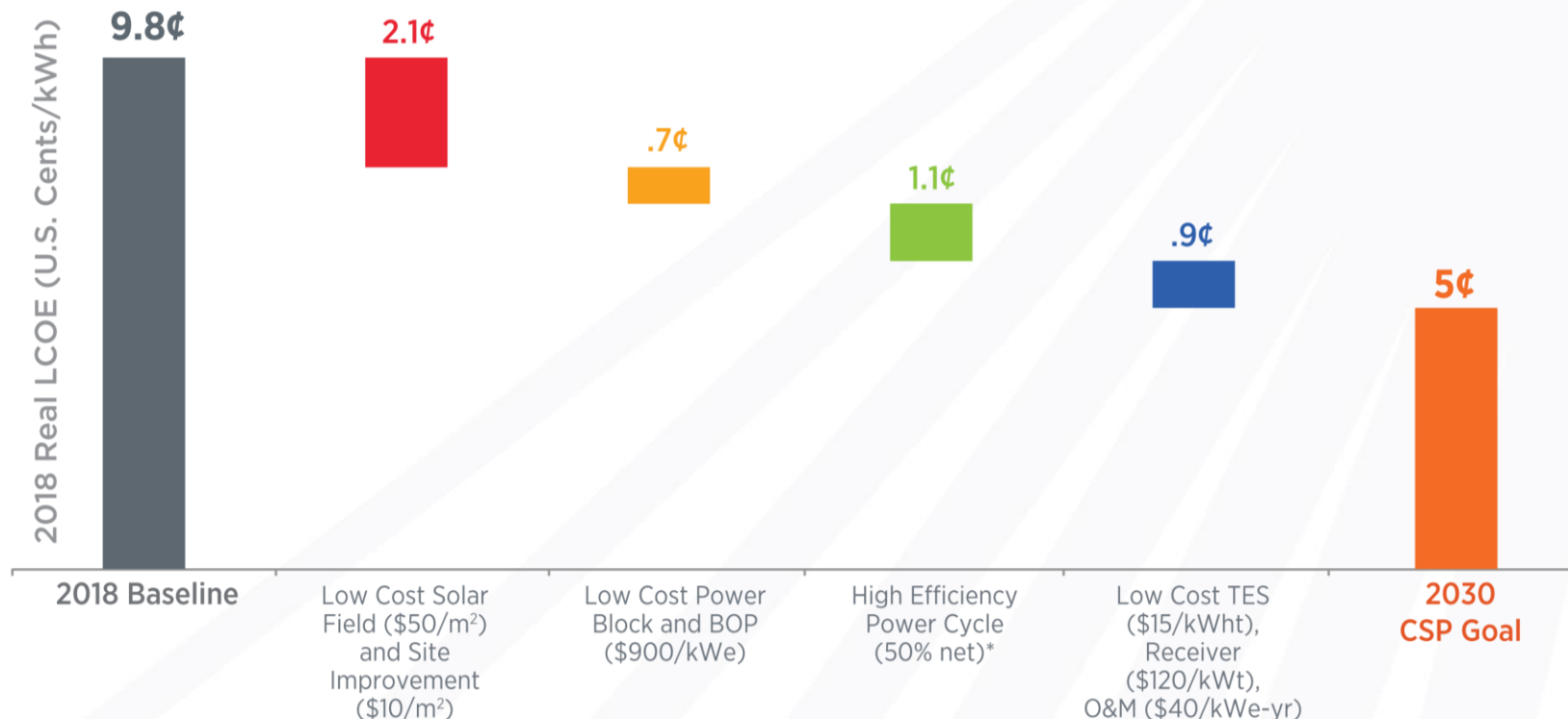


A CSP plant with 12 hours of storage can provide 365-day capacity with 2-5% of the fuel consumption of a natural gas plant

# Solar Thermal can Integrate with the Existing Energy System

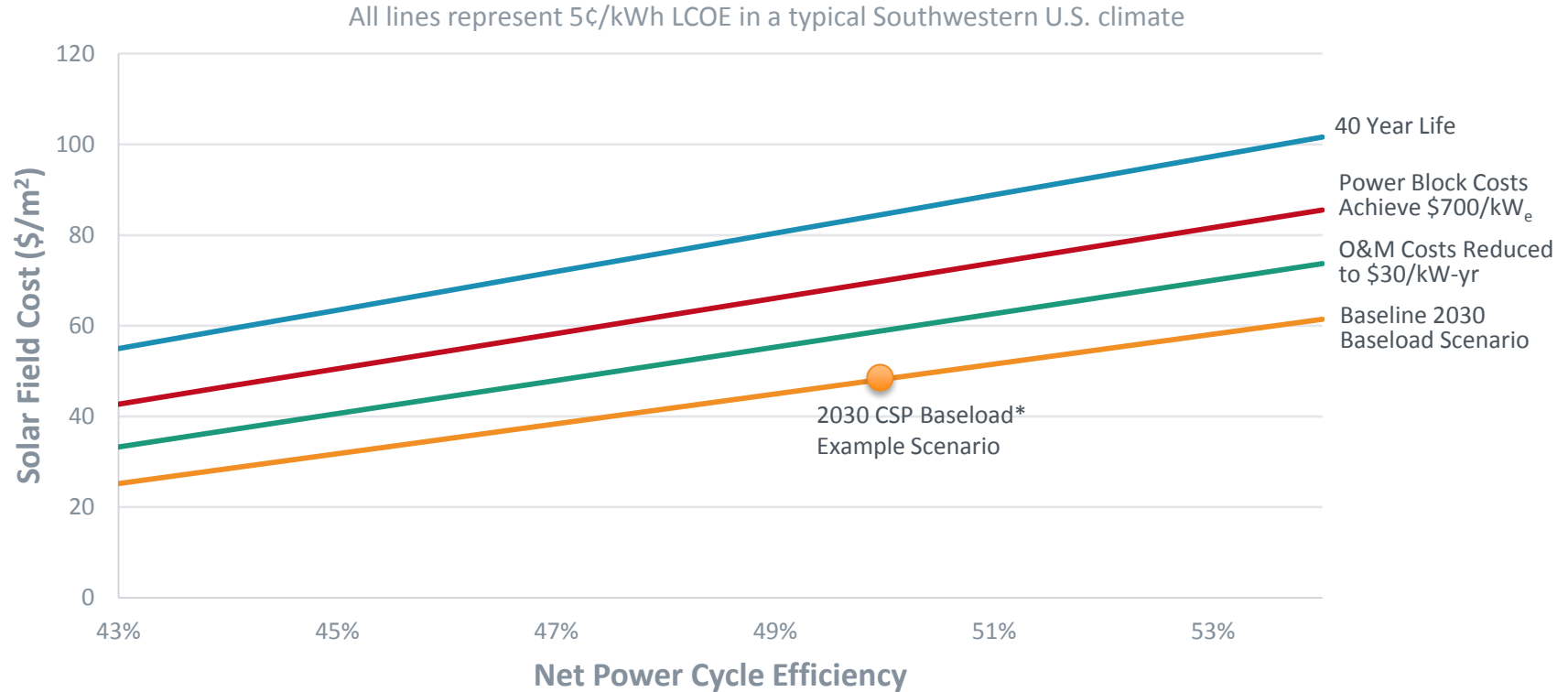


# A Pathway to 5 Cents per KWh for Baseload CSP



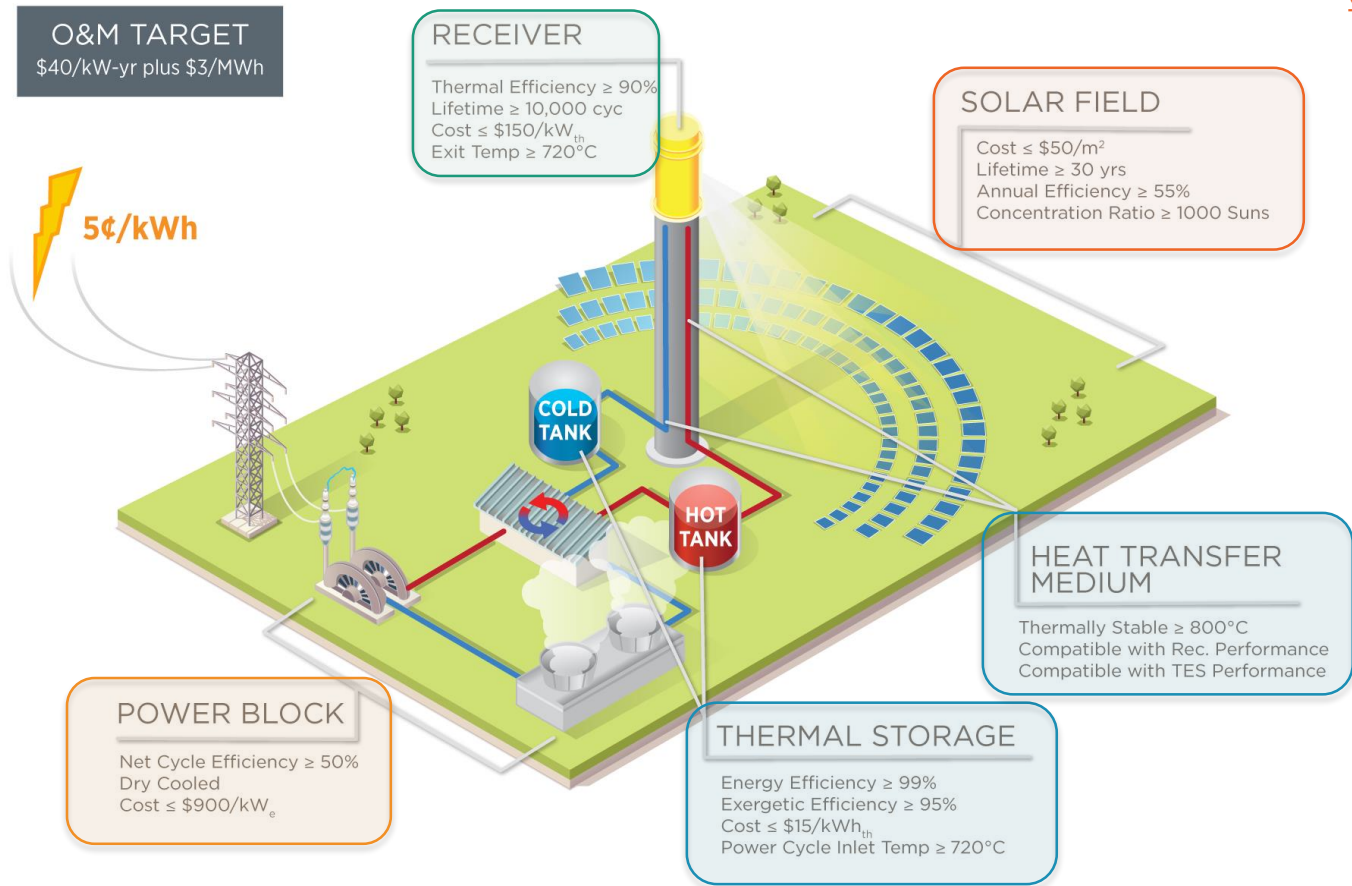
\*Assumes a gross to net conversion factor of 0.9

# Pathways to Achieving SunShot 2030 Goals



\*Baseload power plant is defined as a CSP plant with greater than or equal to 12 hours of storage

# CSP Technical Targets



## Collector Field

- Optical Physics
- Structural design and dynamics
- Manufacturing and automation
- Sensors and control

## Receivers

- Optical properties
- Coatings
- High temperature materials
- Chemistry
- Heat Transfer, Fluid Mechanics

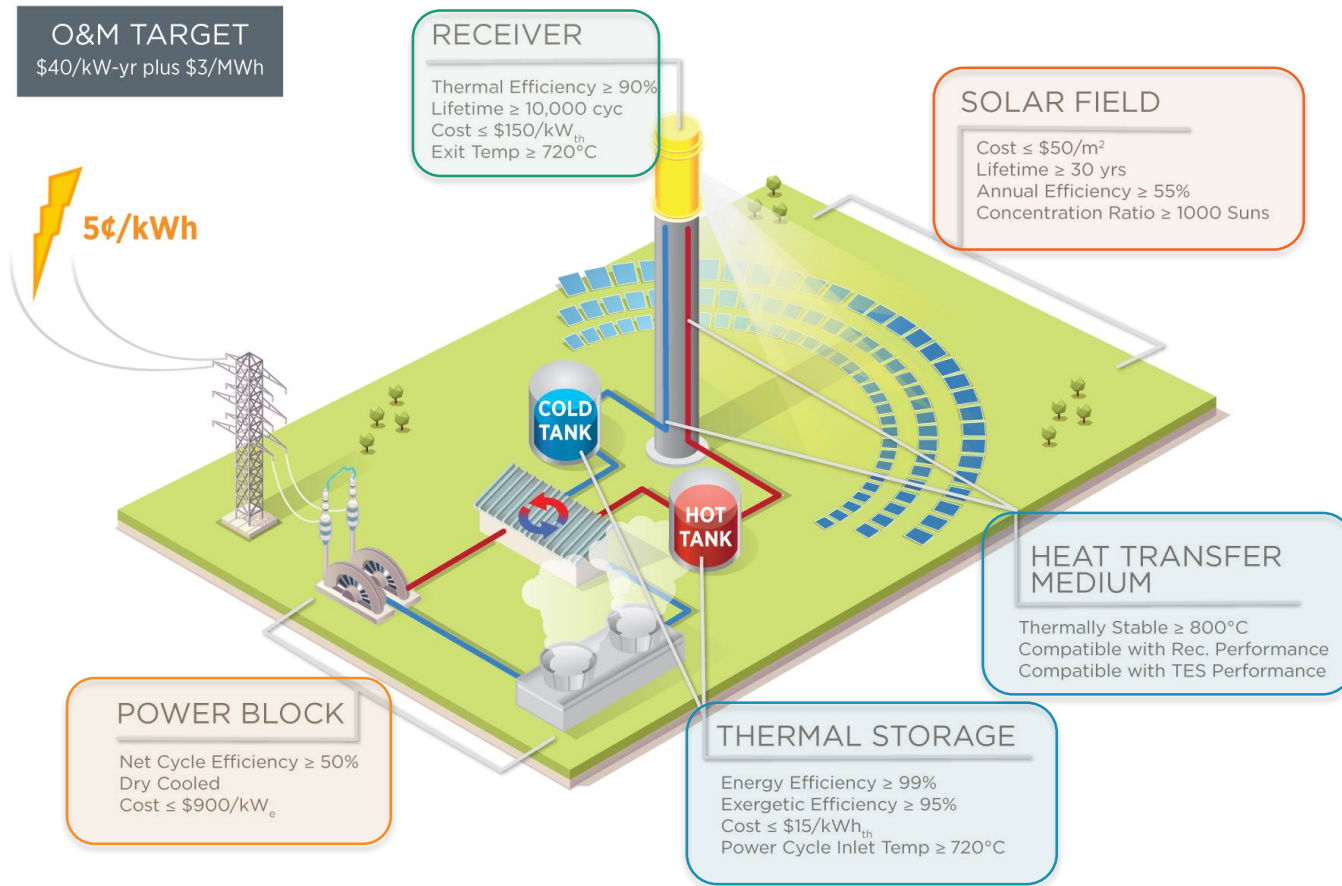
## TES and HTF

- Chemistry
- High temperature materials
- Materials Science
- Heat Transfer, Fluid Mechanics

## Power Block

- High temperature materials
- Turbomachinery
- Manufacturing and automation
- Sensors and control

# CSP Technical Targets



## Competitive Programs

\$43M	FY20 SETO FOA (2020)
\$30M	FY19 SETO FOA (2019)
\$22M	FY18 SETO FOA (2019)
\$21M	Solar Desalination (2018)
\$22M	FY19-21 National Lab Call (2018)
\$70M	Gen3 CSP Systems (2018)
\$15M	Gen3 CSP Lab Support (2018)
\$9M	COLLECTS (2016)
\$32M	CSP: APOLLO (2015)
\$29M	CSP SuNLaMP (2015)
\$1.4M	SolarMat II (2014)
\$10M	CSP: ELEMENTS (2014)
\$1.1M	SunShot Incubator (Recurring)
\$4M	PREDICTS (2013)
\$2M	SolarMat (2013)
\$10M	CSP-HIBRED (2013)
\$27M	National Lab R&D (2012)
\$10M	SunShot MURI (2012)
\$56M	CSP SunShot R&D (2012)
\$0.5M	BRIDGE (2012)
\$62M	CSP Baseload (2010)

# CSP Track Portfolio

CSP Systems

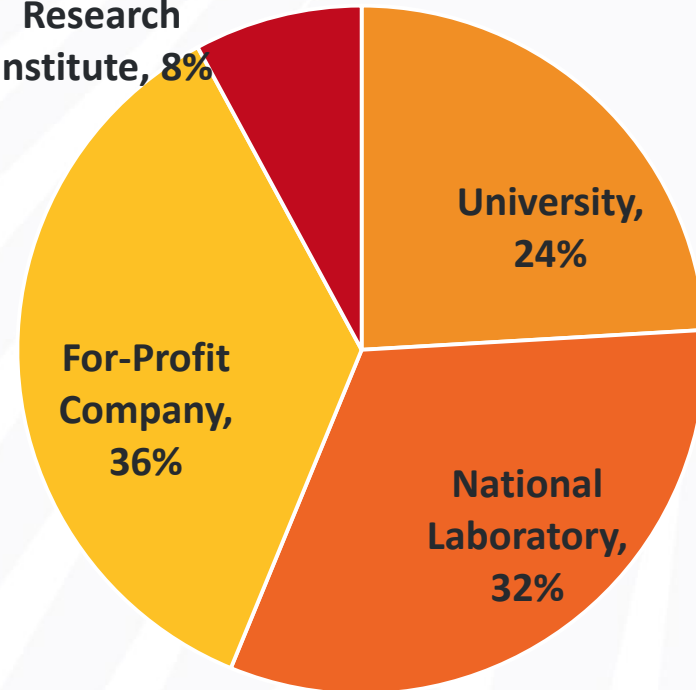
Power Cycles

High-Temperature Thermal Systems

Solar Collectors

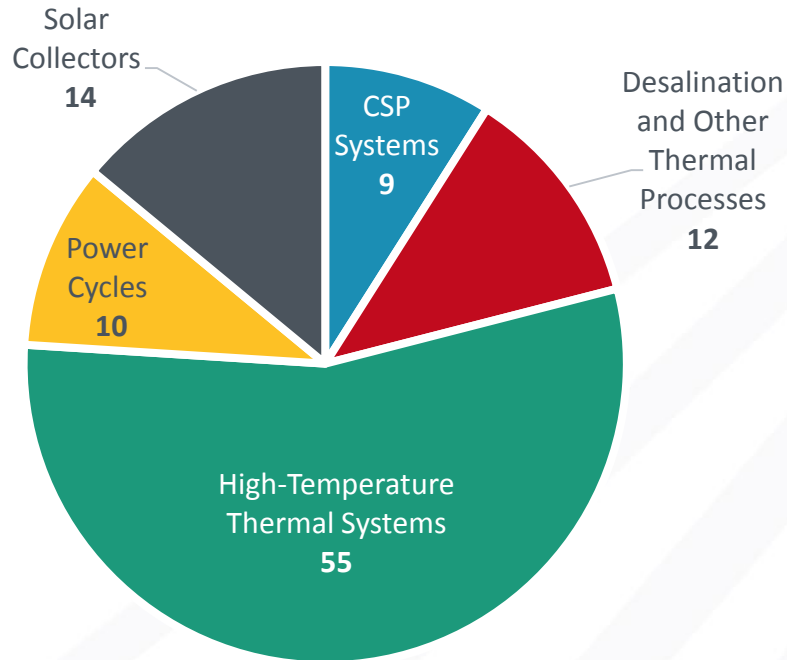
Desalination and Other Industrial Processes

**Non-Profit  
Research  
Institute, 8%**

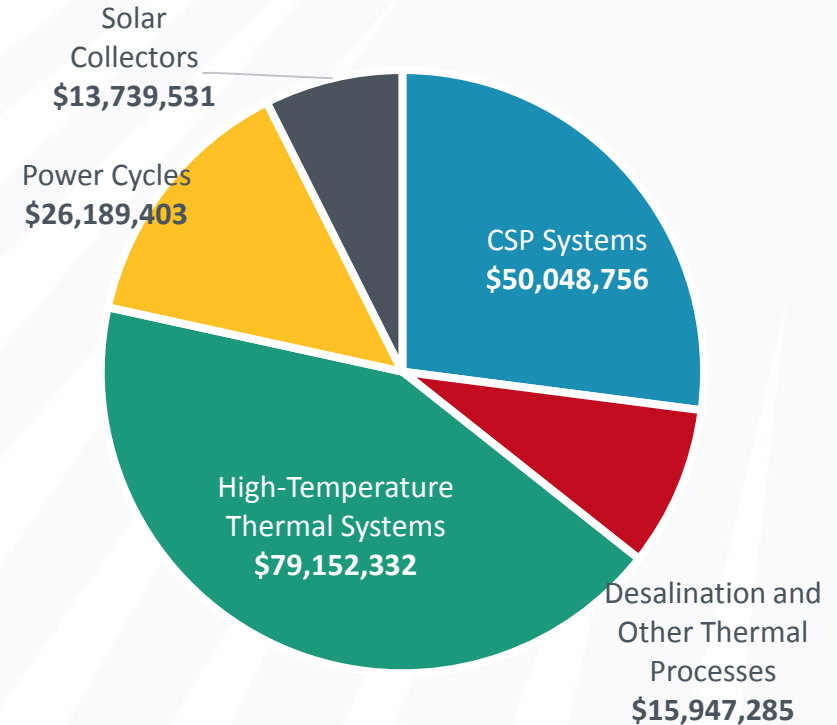


# CSP Portfolio Breakdown by Topic

## Projects by Topic



## Funding by Topic





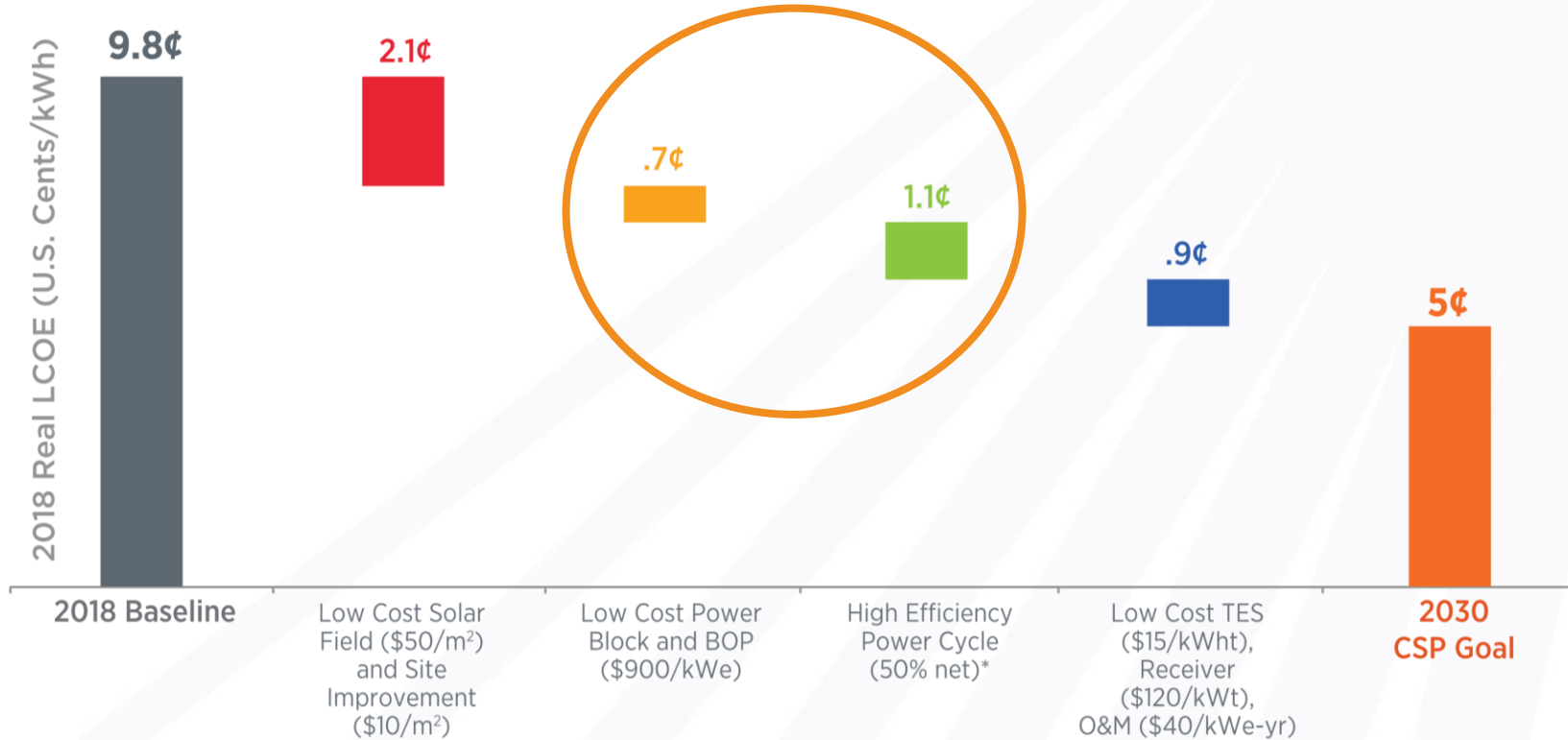
# Topic Areas: CSP Systems



**The CSP track funds work in analysis and development of fully integrated solar thermal systems, including:**

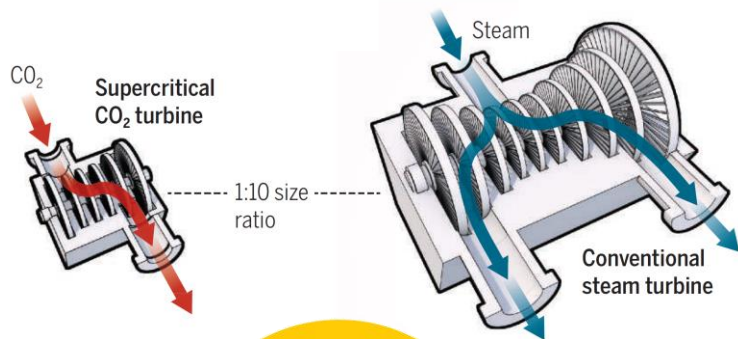
- Market and systems analysis to inform strategic goals
- Gen3 CSP 'Topic 1' teams developing fully integrated systems
- Hardware and modeling tools to improve the performance of existing commercial technologies

# Topic Area: Power Cycles



\*Assumes a gross to net conversion factor of 0.9

# Next Generation CSP will Leverage Next Generation Power Cycles



## Advantages of the sCO<sub>2</sub> Brayton Cycle:

- Higher Efficiency (50% at ~720 C)
- Compact Components
- Smaller Turbine Footprint (by a factor > 10)
- Reduced Power Block Costs
- Amenable to Dry Cooling
- Scalability (Sub 100 MW)
- Operational Simplicity (No Phase Change)

## CSP Specific R&D Challenges

- Higher Temperature Thermal Transport System
- Expanding Temperature Change (Sensible TES)
- Ambient Temperature Variability (Dry Cooling)
- Variable Solar Resource

# Topic Areas: High-Temperature Thermal Systems

$$\eta = 1 - \frac{T_c}{T_H}$$

## GEN3 SYSTEM INNOVATION

CONCENTRATED  
SUNLIGHT

RECEIVER

STORAGE

HEAT  
EXCHANGER

POWER  
CYCLE

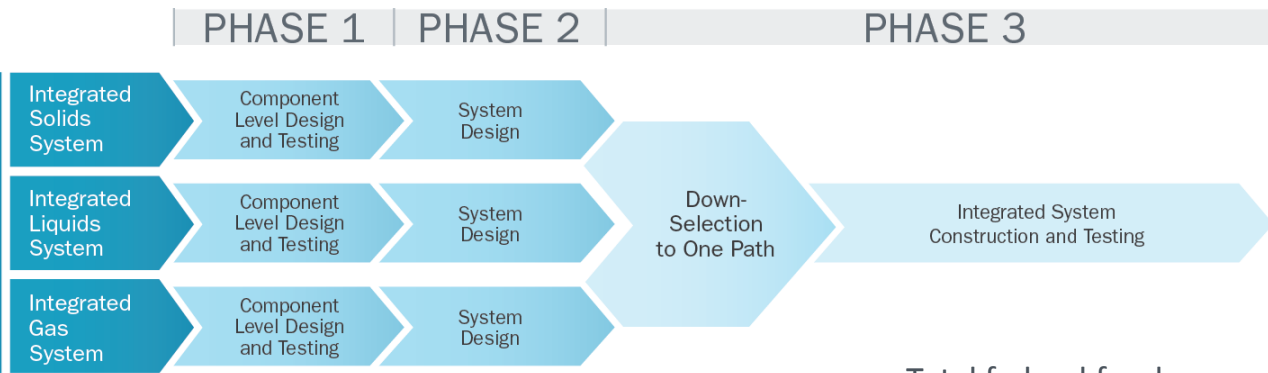
### Sub-topics:

- Gen3 CSP Components
- Thermo-physical/chemical characterization
- Thermal Energy Storage
- Metals and Materials

# Gen3 CSP: Raising the Temperature of Solar Thermal Systems

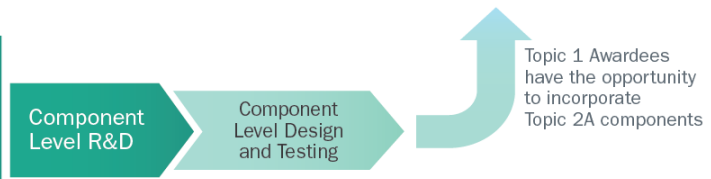
## TOPIC 1

- Sandia National Laboratories
- National Renewable Energy Laboratory
- Brayton Energy



## TOPIC 2A

- Brayton Energy
- Hayward Tyler
- Massachusetts Institute of Technology (x2)
- Mohawk Innovative Technology
- Powdermet
- Purdue University



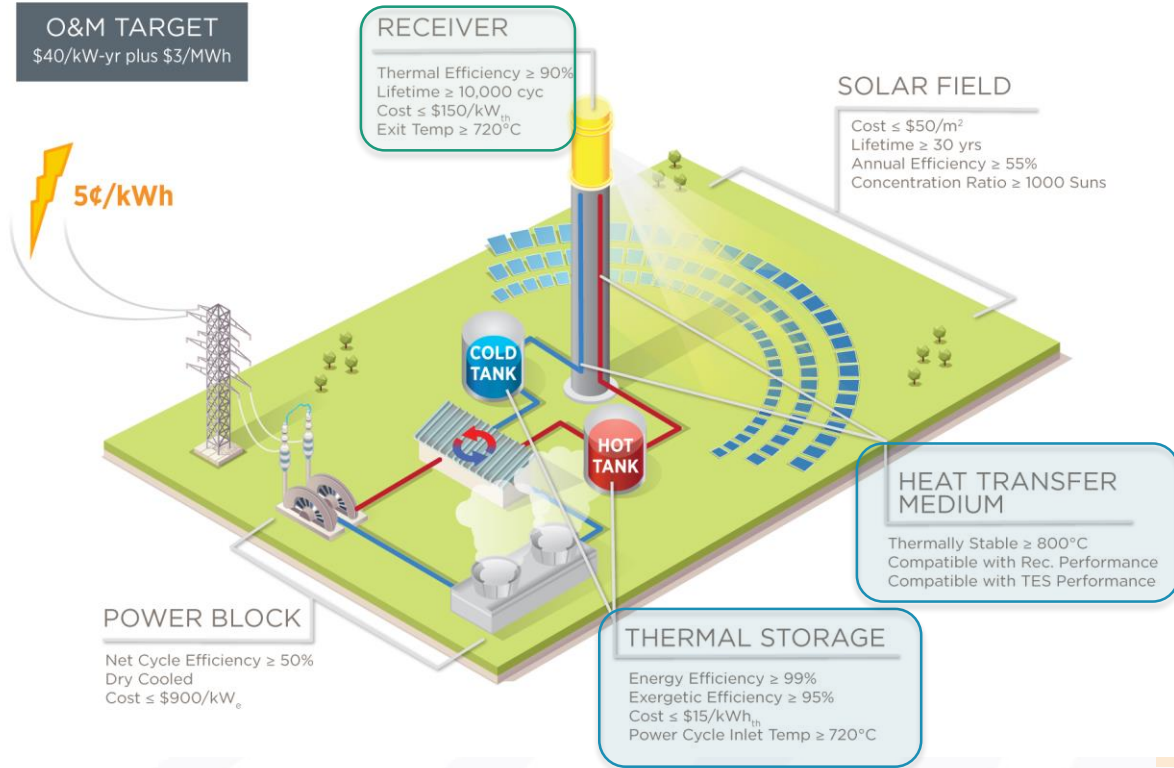
## TOPIC 2B

- Electric Power Research Institute
- Georgia Institute of Technology (x2)
- Rensselaer Polytechnic Institute
- University of California, San Diego
- University of Tulsa



- Total federal funds awarded in 2018: \$85,000,000 over 25 projects in 3 Topics:
  - **Topic 1:** Integrated, multi-MW test facility
  - **Topic 2A:** Individual Component Development
  - **Topic 2B and National Lab Support:** Cross-cutting Gen3 Research and Analysis

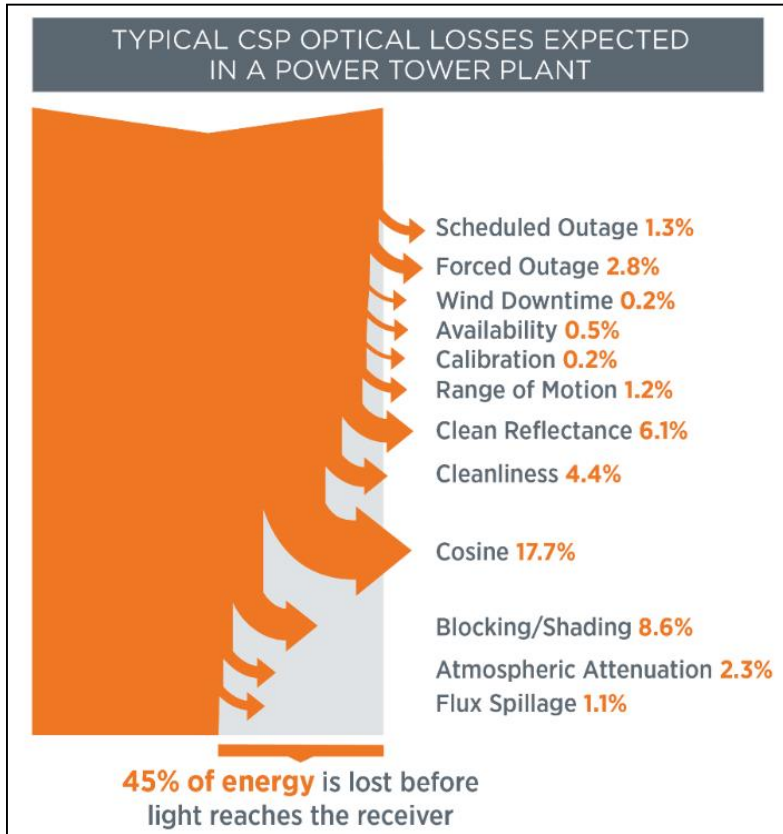
# Topic Areas: High-Temperature Thermal Systems



## Research Areas:

- High-efficiency, stable receiver coatings
- Next-generation Thermal Energy Storage
- Advanced receiver and heat exchanger designs, materials, and manufacturing

# Topic Areas: Solar Collectors

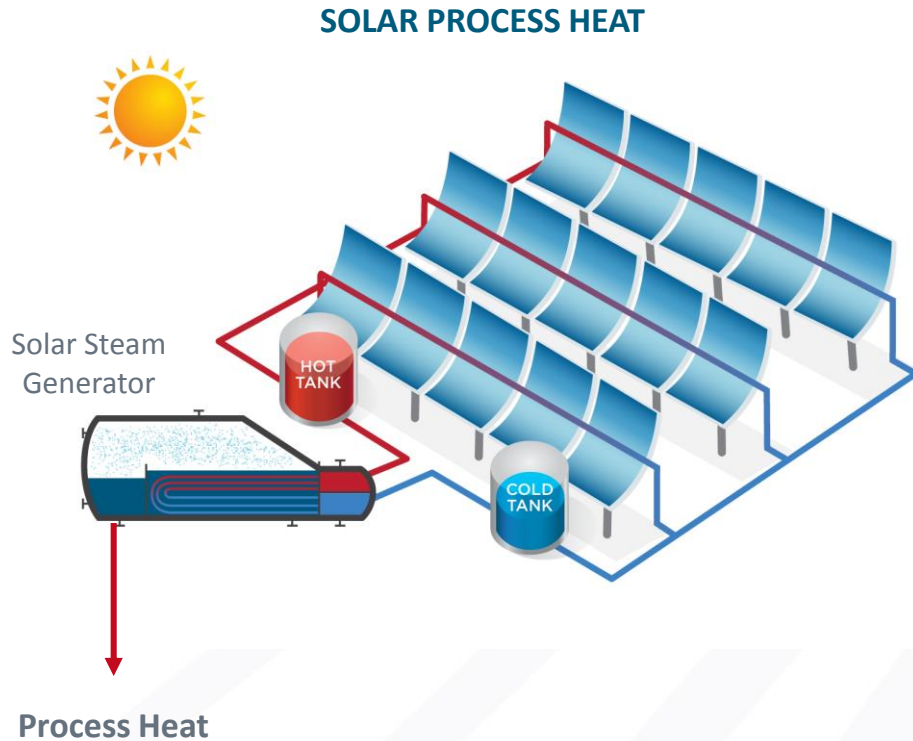


## Priority Areas:

- Reducing installed costs of heliostats and troughs through **simplified designs for manufacturing and installation**
- Reducing capital costs through **non-conventional materials** and components
- Improved performance through **autonomous operation, calibration, and optimization** of components and full systems



# Topic Areas : Desalination and Other Industrial Processes



## Priority Areas:

- Reduce the levelized cost of heat, **with thermal energy storage**, in temperature ranges of high priority to industrial processes
- Improve the **thermal efficiency** of solar-thermal-coupled processes
- Develop long-duration, thermochemical storage of solar energy (i.e. **solar fuels** and chemical commodities)



# Topic Areas : Desalination and Other Industrial Processes



- Multi-million dollar prize was announced on September 25, 2019
- Multi-phase competition, progressing from concept design through demonstration
- Will seek to connect technology developers with test facilities and potential customers

# SolarPACES 2020 Conference



**SolarPACES 2020** will be held in **Albuquerque, New Mexico, USA** from **September 29 – October 2, 2020**.

Call for Abstracts available at  
<http://www.solarpaces-conference.org/>

Abstract Due Date: May 1, 2020

**SolarPACES** (Solar Power and Chemical Energy Systems) is the premier international conference and network for **advancing commercial deployment and research and development** of concentrating solar-thermal power (CSP) and related technologies.

Technology Managers



Mark Lausten, PE  
On contract from BGS



Levi Irwin, PhD  
On contract from Mantech



Matt Bauer, PhD



Nikkia McDonald, PhD



Christine Bing, MBA



Andru Prescod, PhD, MBA  
On contract from Mantech



Rajgopal 'Vijay'  
Vijaykumar, PhD



Shane Powers  
On contract from Mantech

Financial Analyst



Patty Clark, MBA  
On contract from Allegheny S&T

Operations



Meisha Baylor  
On contract from Red Horse

Science and Technology Policy Fellow  
Technical Project Officer

# Agenda – Monday, April 6

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Time	Session
1:30PM–2:00PM	<b>CSP Track Introduction</b> <i>Avi Shultz, Program Manager</i>
2:00PM-2:15PM	<b>CSP Review Panel Introduction</b> <i>Fred Redell, Chair, CSP Track Review Panel</i>
2:15PM-3:00PM	<b>High-Temperature Thermal Systems: Gen3 CSP Overview</b> <i>Matt Bauer, Technology Development Manager</i> <i>Shane Powers, Technology Development Manager</i>
3:00PM-4:00PM	<b>High-Temperature Thermal Systems: Gen3 CSP Discussion</b> <i>All</i>
4:00PM-5:00PM	<b>Internal Review Panel Discussion</b>

# Agenda – Tuesday, April 7

Time	Session
11:00AM–11:10AM	<b>CSP Systems: Analysis and Commercial Support Overview</b> <i>Mark Lausten, Technology Development Manager</i>
11:10AM–11:30AM	<b>CSP Systems: Analysis and Commercial Support Discussion</b> <i>All</i>
11:30AM–11:50AM	<b>Power Cycles: Supercritical CO<sub>2</sub> Brayton Cycle Development Overview</b> <i>Rajgopal Vijaykumar, Technology Development Manager</i>
11:50AM–12:30PM	<b>Power Cycles: Supercritical CO<sub>2</sub> Brayton Cycle Development Discussion</b> <i>All</i>
12:30PM–12:45PM	<b>Desalination and Other Industrial Processes Overview</b> <i>Andru Prescod, Technology Development Manager</i>
12:45PM–1:15PM	<b>Desalination and Other Industrial Processes Discussion</b> <i>All</i>

Time	Session
1:15PM–1:45PM	<b>Break/Lunch</b>
1:45PM–2:00PM	<b>Solar Collectors Overview</b> <i>Andru Prescod, Technology Development Manager</i>
2:00PM–2:45PM	<b>Solar Collectors Discussion</b> <i>All</i>
2:45PM–3:00PM	<b>High-Temperature Thermal Systems, Part 2 Overview</b> <i>Levi Irwin, Technology Development Manager</i>
3:00PM–3:35PM	<b>High-Temperature Thermal Systems, Part 2 Discussion</b> <i>All</i>
3:35PM–3:40PM	<b>Single Year R&amp;D Programs Overview</b> <i>Matt Bauer, Technology Development Manager</i>
3:40PM–4:00PM	<b>Single Year R&amp;D Programs Discussion</b> <i>All</i>
4:00PM–5:00PM	<b>Internal Review Panel Discussion</b>

# Agenda – Wednesday, April 7

Time	Session
11:00AM–12:30PM	<b>Internal Review Panel Discussion (Avi available for Questions)</b>
12:30PM–12:45PM	<b>Break</b>
12:45PM–2:15PM	<b>Reviewer Roundtable with SETO Staff</b>
2:15PM–2:45PM	<b>Break</b>
2:45PM–3:45PM	<b>Track Chairs Discussion with Planning and Strategy Reviewers</b>
3:45PM–4:00PM	<b>Break</b>
4:00PM–5:00PM	<b>Track Chairs and P&amp;S Roundtable with SETO Leadership</b>



Office of ENERGY EFFICIENCY  
& RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

# Thank You

[energy.gov/solar-office](https://energy.gov/solar-office)

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[Avi.Shultz@ee.doe.gov](mailto:Avi.Shultz@ee.doe.gov)